

WHAT IS CLAIMED IS:

1 1. A waveguide-type optical control device comprising:

2 first and second directional couplers provided while
3 leaving a predetermined spacing therebetween, said first and
4 second directional couplers being constituted respectively by
5 two right and left optical waveguides provided on a substrate;
6 and

7 a control unit provided between the first directional
8 coupler and the second directional coupler, first, second, and
9 third electrodes being provided respectively on the left side
10 of the left optical waveguide, on the right side of the right
11 optical waveguide, and between the two optical waveguides, said
12 control unit functioning to control light, which passes through
13 the two optical waveguides, according to a voltage applied to
14 the first, second, and third electrodes,

15 said first, second, and third electrodes being extended
16 into the first and second directional couplers.

1 2. The waveguide-type optical control device according to
2 claim 1, wherein the first and second electrodes are different
3 from each other in shape.

1 3. The waveguide-type optical control device according to
2 claim 1, wherein the first, second, and third electrodes are
3 extended to a portion near the boundary between the first
4 directional coupler and the control unit and the boundary
5 between the second directional coupler and the control unit.

1 4. The waveguide-type optical control device according to
2 claim 1, wherein the first, second, and third electrodes have
3 been offset to the right or left side with respect to the
4 center line between the two optical waveguides.

1 5. The waveguide-type optical control device according to
2 claim 1, wherein the control unit is a phase shifter that
3 controls the quantity of light, which passes through the two
4 optical waveguides, according to the applied voltage.

1 6. A waveguide-type optical control device comprising:

2 a phase shifter provided with a first electrode section
3 comprising an electrode provided on the left side of a left
4 optical waveguide, an electrode provided on the right side of a
5 right optical waveguide, and an electrode provided between the
6 two optical waveguides; and

7 a directional coupler comprising two optical waveguides
8 which are connected respectively to the two right and left
9 optical waveguides in the phase shifter and are provided
10 parallel to each other with the spacing between the two optical
11 waveguides being partially reduced, said directional coupler
12 being used in at least one of an optical branching section
13 provided on the input side of the phase shifter and an optical
14 coupling section provided on the output side of the phase
15 shifter, the refractive index of the two optical waveguides
16 being varied according to a voltage applied across the
17 electrodes provided respectively on the left side of the left

18 optical waveguide and the right side of the right optical
19 waveguide and the electrode provided between the two optical
20 waveguides in the phase shifter,

21 said directional coupler being provided with a second
22 electrode section comprising an electrode provided on the left
23 side of the left optical waveguide, an electrode provided on
24 the right side of the right optical waveguide, and an electrode
25 provided between the two optical waveguides, the three
26 electrodes constituting the second electrode section being
27 electrically connected respectively to the three electrodes
28 constituting the first electrode section provided adjacent to
29 the second electrode section in the longitudinal direction of
30 the two optical waveguides, the voltage applied to the first
31 electrode section being applied to the second electrode section.

1 7. The waveguide-type optical control device according to
2 claim 6, wherein the second electrode section has been formed
3 by extending the electrodes constituting the first electrode
4 section.

1 8. The waveguide-type optical control device according to
2 claim 6, wherein the second electrode section has a
3 construction such that the shape of the electrode provided on
4 the left side of the left optical waveguide and the shape of
5 the electrode provided on the right side of the right optical
6 waveguide are asymmetrical.

1 9. The waveguide-type optical control device according to

2 claim 6, wherein the second electrode section is provided only
3 at a portion near the boundary between the directional coupler
4 and the phase shifter.

1 10. The waveguide-type optical control device according
2 to claim 6, wherein the first electrode section and the second
3 electrode section have been offset by a predetermined level
4 with respect to the center line between the two optical
5 waveguides.

1 11. The waveguide-type optical control device according
2 to claim 6, wherein, in the second electrode section, the
3 electrode provided on the left side of the left optical
4 waveguide and the electrode provided on the right side of the
5 right optical waveguide each comprise a plurality of electrode
6 pieces which are arranged at a predetermined interval and have
7 been connected to each other or one another through a fuse or a
8 bonding wire.

1 12. The waveguide-type optical control device according
2 to claim 6, wherein the electrode provided between the optical
3 waveguides in the second electrode section partially or
4 entirely overlaps with one of the two optical waveguides in the
5 thicknesswise direction thereof.

1 13. The waveguide-type optical control device according
2 to claim 6, wherein the second electrode section is disposed on
3 the surface of a substrate on which the two optical waveguides

4 are provided through a buffer layer.

1 14. The waveguide-type optical control device according
2 to claim 6, wherein each of the electrodes constituting the
3 second electrode section is disposed so as to be substantially
4 coplanar with the two optical waveguides.

1 15. The waveguide-type optical control device according
2 to claim 14, wherein the electrodes constituting the second
3 electrode section are provided within respective concaves
4 provided on the surface of a substrate on which the two optical
5 waveguides are provided.

1 16. The waveguide-type optical control device according
2 to claim 6, wherein the second electrode section is disposed on
3 the backside of a substrate on which the two optical waveguides
4 are provided.

1 17. The waveguide-type optical control device according
2 to claim 6, 7, 8, 9, 10, 13, or 16, wherein the directional
3 coupler is provided in each of the optical branching section
4 and the optical coupling section and both the directional
5 couplers are provided with the second electrode section.

1 18. A waveguide-type optical control device comprising:
2 a phase shifter comprising two left and right optical
3 waveguides, a first electrode provided on the left side of the
4 left optical waveguide, a second electrode provided on the

5 right side of the right optical waveguide, and a third
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end
8 of the phase shifter and functions to branch an optical signal
9 introduced through one of the two optical waveguides into
10 optical signal parts which are then introduced respectively
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the
13 other end of the phase shifter and functions to couple the
14 optical signal parts received respectively from the two optical
15 waveguides,

16 at least one of the first and second electrodes and the
17 third electrode having been extended into a part or the whole
18 of the first directional coupler or the second directional
19 coupler.

1 19. A waveguide-type optical control device comprising:

2 a phase shifter comprising two left and right optical
3 waveguides, a first electrode provided on the left side of the
4 left optical waveguide, a second electrode provided on the
5 right side of the right optical waveguide, and a third
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end
8 of the phase shifter and functions to branch an optical signal
9 introduced through one of the two optical waveguides into
10 optical signal parts which are then introduced respectively
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the

13 other end of the phase shifter and functions to couple the
14 optical signal parts received respectively from the two optical
15 waveguides,

16 at least one of the first and second electrodes and the
17 third electrode having been extended into a part or the whole
18 of the first directional coupler, at least one of the first and
19 second electrodes and the third electrode having been extended
20 into a part or the whole of the second directional coupler.

21 20. A waveguide-type optical control device comprising:

22 a phase shifter comprising two left and right optical
23 waveguides, a first electrode provided on the left side of the
24 left optical waveguide, a second electrode provided on the
25 right side of the right optical waveguide, and a third
26 electrode provided between the two optical waveguides;

27 a first directional coupler that is connected to one end
28 of the phase shifter and functions to branch an optical signal
29 introduced through one of the two optical waveguides into
30 optical signal parts which are then introduced respectively
31 into the two optical waveguides; and

32 a second directional coupler that is connected to the
33 other end of the phase shifter and functions to couple the
34 optical signal parts received respectively from the two optical
35 waveguides,

36 said first directional coupler comprising, in its
37 directional coupling section, first directional coupling
38 section outer electrodes disposed respectively at a portion
39 near the left side of the left optical waveguide and at a

20 portion near the right side of the right optical waveguide in
 21 the first directional coupling section and a first directional
 22 coupling section intermediate electrode disposed between the
 23 two optical waveguides in the first directional coupling
 24 section,

25 said first electrode and said second electrode having
 26 been electrically connected respectively to the first
 27 directional coupling section outer electrodes, said third
 28 electrode having been electrically connected to the first
 29 directional coupling section intermediate electrode.

1 21. The waveguide-type optical control device according
 2 to claim 20, wherein the first directional coupling section
 3 outer electrodes and the first directional coupling section
 4 intermediate electrode apply a voltage to a part of the optical
 5 waveguides constituting the directional coupling section to
 6 cause an electric field.

1 22. A waveguide-type optical control device comprising:
 2 a phase shifter comprising two left and right optical
 3 waveguides, a first electrode provided on the left side of the
 4 left optical waveguide, a second electrode provided on the
 5 right side of the right optical waveguide, and a third
 6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end
 8 of the phase shifter and functions to branch an optical signal
 9 introduced through one of the two optical waveguides into
 10 optical signal parts which are then introduced respectively

11 into the two optical waveguides; and

12 a second directional coupler that is connected to the
13 other end of the phase shifter and functions to couple the
14 optical signal parts received respectively from the two optical
15 waveguides,

16 said second directional coupler comprising, in its
17 directional coupling section, second directional coupling
18 section outer electrodes disposed respectively at a portion
19 near the left side of the left optical waveguide and at a
20 portion near the right side of the right optical waveguide in
21 the second directional coupling section and a second
22 directional coupling section intermediate electrode disposed
23 between the two optical waveguides in the second directional
24 coupling section,

25 said first electrode and said second electrode having
26 been electrically connected respectively to the second
27 directional coupling section outer electrodes, said third
28 electrode having been electrically connected to the second
29 directional coupling section intermediate electrode.

1 23. The waveguide-type optical control device according
2 to claim 22, wherein the second directional coupling section
3 outer electrodes and the second directional coupling section
4 intermediate electrode apply a voltage to a part of the optical
5 waveguides constituting the directional coupling section to
6 cause an electric field.

1 24. The waveguide-type optical control device according

to claim 20 or 21, wherein the first directional coupling section intermediate electrode has been offset with respect to the center line between the two optical waveguides constituting the first directional coupling section.

25. The waveguide-type optical control device according to claim 22 or 23, wherein the second directional coupling section intermediate electrode has been offset with respect to the center line between the two optical waveguides constituting the second directional coupling section.

26. A variable optical attenuator comprising:

a phase shifter provided with a first electrode section comprising an electrode provided on the left side of a left optical waveguide, an electrode provided on the right side of a right optical waveguide, and an electrode provided between the two optical waveguides; and

a directional coupler comprising two optical waveguides which are connected respectively to the two optical waveguides in the phase shifter and are provided parallel to each other with the spacing between the two optical waveguides being partially reduced, said directional coupler being used in at least one of an optical branching section provided on the input side of the phase shifter and an optical coupling section provided on the output side of the phase shifter, the refractive index of the two optical waveguides being varied according to a voltage applied across the electrodes provided respectively on the left side of the left optical waveguide and

18 the right side of the right optical waveguide and the electrode
19 provided between the two optical waveguides in the phase
20 shifter, whereby the attenuation level of the lights passed
21 through the optical waveguides is controlled,

22 said directional coupler being provided with a second
23 electrode section comprising an electrode provided on the left
24 side of the left optical waveguide, an electrode provided on
25 the right side of the right optical waveguide, and an electrode
26 provided between the two optical waveguides, the three
27 electrodes constituting the second electrode section being
28 electrically connected respectively to the three electrodes
29 constituting the first electrode section provided adjacent to
30 the second electrode section in the longitudinal direction of
31 the two optical waveguides, the voltage applied to the first
32 electrode section being applied to the second electrode section.

1 27. An optical equalizer comprising:

2 an optical demultiplexer into which a wavelength
3 multiplexed optical signal containing a plurality of optical
4 signals with one or mutually different wavelengths is input and
5 which demultiplexes the wavelength multiplexed optical signal
6 into optical signals and outputs the demultiplexed optical
7 signals;

8 the variable optical attenuator according to claim 26
9 which selectively attenuates the demultiplexed optical signals
10 by a predetermined attenuation level and outputs the attenuated
11 optical signals; and

12 an optical multiplexer for multiplexing the attenuated

13 optical signals output from the variable optical attenuator.

1 28. The optical equalizer according to claim 27, which
2 further comprises an attenuation level control circuit for
3 controlling the variable optical attenuator so as to render the
4 optical levels of the attenuated optical signals homogeneous.

1 29. The optical equalizer according to claim 27, which
2 further comprises an attenuation level control circuit for
3 controlling the variable optical attenuator in such a manner
4 that a predetermined difference is provided between the optical
5 levels of the attenuated optical signals.

1 30. An optical inserting/separating apparatus comprising:
2 an optical demultiplexer into which a wavelength
3 multiplexed optical signal containing a plurality of optical
4 signals with one or mutually different wavelengths is input and
5 which demultiplexes the wavelength multiplexed optical signal
6 into optical signals and outputs the demultiplexed optical
7 signals;

8 a wavelength varying filter for selectively separating an
9 optical signals with predetermined wavelengths from the
10 demultiplexed optical signals;

11 the variable optical attenuator according to claim 26
12 which selectively attenuates the demultiplexed optical signals,
13 which have passed through the wavelength varying filter, by a
14 predetermined attenuation level and outputs the attenuated
15 optical signals; and

16 a filter which selects and outputs the attenuated optical
17 signals from the variable optical attenuator or externally
18 inserted optical signals; and

19 an optical multiplexer for multiplexing the attenuated
20 optical signals output from the filter or the inserted optical
21 signals.

1 31. The optical inserting/separating apparatus according
2 to claim 30, which further comprises an attenuation level
3 control circuit for controlling the variable optical attenuator
4 so as to render the optical levels of the attenuated optical
5 signals and the inserted optical signals homogeneous.

1 32. The optical inserting/separating apparatus according
2 to claim 30, which further comprises an attenuation level
3 control circuit for controlling the variable optical attenuator
4 so as to provide a predetermined difference between the optical
5 levels of the attenuated optical signals and the inserted
6 optical signals.

1 33. A waveguide-type optical control device comprising:
2 a phase shifter comprising two left and right optical
3 waveguides, a first electrode provided on the left side of the
4 left optical waveguide, a second electrode provided on the
5 right side of the right optical waveguide, and a third
6 electrode provided between the two optical waveguides;
7 a first directional coupler that is connected to one end
8 of the phase shifter and functions to branch an optical signal

9 introduced through one of the two optical waveguides into
10 optical signal parts which are then introduced respectively
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the
13 other end of the phase shifter and functions to couple the
14 optical signal parts received respectively from the two optical
15 waveguides,

16 at least one of the first and second electrodes and the
17 third electrode having been extended into a part or the whole
18 of the first directional coupler or the second directional
19 coupler, the third electrode in its extended electrode portion
20 being provided so that a longitudinal electric field is applied
21 to one of the two optical waveguides.

22 34. The waveguide-type optical control device according
23 to claim 33, wherein the third electrode in its extended
24 electrode portion is disposed on the top surface or the
25 backside of one of the two optical waveguides so as to overlap
26 therewith.

27 35. A process for producing a waveguide-type optical
28 control device, comprising the steps of:

29 forming two right and left optical waveguides so as to
30 construct a phase shifter and at least one directional coupler
31 within a substrate;

32 forming a first electrode and a second electrode
33 respectively on the left side of the left optical waveguide and
34 on the right side of the right optical waveguide so as to

9 extend from the phase shifter to a part of the directional
10 coupler, forming a third electrode between the two optical
11 waveguides so as to extend from the phase shifter to a part of
12 the directional coupler, and, in addition, forming a plurality
13 of independent electrode pieces at a predetermined interval at
14 the end of the second electrode and at the end of the third
15 electrode, or forming a plurality of electrode pieces at a
16 predetermined interval connected to each other or one another
17 in a cascade form through a fuse; and

18 successively wire bonding the necessary number of the
19 plurality of independent electrode pieces from the inner side,
20 or successively fusion cutting the fuse of the necessary number
21 of the plurality of cascaded electrode pieces from the outer
22 side so as to bring the characteristic value of the directional
23 coupler to a desired value.